FACTOR STRUCTURE OF THE NEUROCOGNITIVE BATTERY IN A GERIATRIC

SAMPLE WITH COGNITIVE IMPAIRMENTS

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The present study was designed to empirically validate six theoretically derived cognitive domains (verbal memory, visual memory, working memory, attention-concentration, executive functions, and visuospatial abilities) assessed by a comprehensive battery of neuropsychological tests used in the Geriatric Memory Clinic at the University of North Texas Health Science Center in Fort Worth, Texas. The study examined the extent to which various cognitive dimensions are tapped by this battery in a heterogeneous geriatric sample of 114 patients with cognitive impairments. The proposed six-factor model of cognitive functioning has not been supported. Further exploratory factor analysis arrived at a five-factor solution. Factor pattern of the 23 tests supported the following five dimensions: memory, executive control, attention, visuospatial abilities, and cognitive flexibility.

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INTRODUCTION

Purpose of the Study

The purpose of the present study is to evaluate the factor structure of the neuropsychological battery using confirmatory factor analysis. The study was designed to empirically validate cognitive domains assessed by a comprehensive battery of neuropsychological tests used in the Geriatric Memory Clinic at the University of North Texas Health Science Center in Fort Worth, Texas. The battery provides an assessment of cognitive abilities in patients with suspected or diagnosed cognitive impairment or dementia. The study will examine the extent to which various cognitive dimensions are tapped by this battery in the heterogeneous geriatric population with cognitive impairments. In interpretation of the battery, tests have been grouped into six domains based on face validity and construct validity established by previous research. A confirmatory factor analysis was used to confirm the six-factor model: Working Memory, Attention-Concentration, Executive Function, Visuospatial Abilities, Verbal Memory and Visual Memory.

The following tests were included in the analysis: The Hooper Visual Organization Test; Wechsler Memory Scale-Third Edition™ (WMS-III; Wechsler, 1997) instrument (Harcourt Assessment, Inc., San Antonio, TX) subtests - Logical Memory I, Logical Memory II, Logical Memory Recognition, Visual Reproduction I, Visual Reproduction II, Visual Reproduction Recognition, Letter-Number Sequencing, Mental Control, Digit Span, and Spatial Span; Consortium to Establish a Registry for Alzheimer's Disease subtests - Verbal Fluency, Boston Naming Test, Word List Memory Task, Word List Recall Task, Word List Recognition Task, and Constructional Praxis; Behavioral Dyscontrol Scale; Trailmaking Test A; Trailmaking Test

B; and Clock Drawing Test. The discussion below provides a review of research literature on construct validity of individual tests used in the neuropsychological battery.

Hooper Visual Organization Test

The Hooper Visual Organization Test (HVOT; Hooper, 1958) is used as a measure of visual perceptual function. It is referred to as a clinical measure of non-dominant hemisphere function (Paul et al., 2001). It was originally designed to identify mental hospital patients with brain dysfunction (Hooper). The task consists 30 drawings of objects that have been cut up and the parts have been rearranged. Patients need to mentally rearrange the parts and name the object.

Spreen and Strauss (1998) described the HVOT as a test that demands "perceptual differentiation and conceptual reorganization (including mental rotation) of the fragmented objects" (p. 509). Research indicates that successful performance on the HVOT requires intact visual perceptual organization skills and to a lesser degree intact confrontational naming ability. The HVOT scores were consistently found to be strongly correlated with the Wechsler Adult Intelligence Scale - Revised™ (WAIS-R; Wechsler, 1981) instrument (Psychological Corporation, San Antonio, TX) Performance subtests (Johnstone & Wilhelm, 1997) and the WAIS-R Perceptual Organization factor score (Ricker & Axelrod, 1995). The Perceptual Organization factor score accounted for 42% (Greve, Lindberg, Bianchini, & Adams, 2000) and 44% (Ricker & Axelrod) of the variance in the HVOT performance, suggesting that it measures a construct similar to that measured by WAIS-R performance subtests. Among the Wechsler scale subtests, performance subtests of Picture Completion (a measure of visual reasoning, organization, and detail analysis) and Object Assembly (a measure of visual organizational speed) had the strongest relation with the HVOT, accounting for 40% and 35 of the HVOT variance, respectively (Greve et al., 2000; Ricker & Axelrod). To examine the role of mental assembly for task completion, Jonsdottir (1997) showed only the most informative piece of each item to individuals, and found that they were able to successfully identify most objects. He concluded that the HVOT has more in common with a naming test than a test of mental object assembly. The actual mental assembly may be required only the most difficult items.

Research about the role of object naming ability or confrontational naming ability in performance on the HVOT is conflicting. Two studies evaluated relationship between WAIS-R, the HVOT and naming tests, and found that naming ability contributed 11% (Ricker & Axelrod, 1995) and 15% (Greve et al., 2000) of the HVOT variance. Paolo, Cluff, and Ryan (1996) found no significant difference on the HVOT performance between patients with intact versus compromised naming ability as measured by the Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1983) and concluded that successful performance on the test depends more on a perceptual-organizational skills. In contrast, Cirillo, Swearer, Kane, and Lavoie (1999) found that individuals with compromised naming ability, as measured by the BNT performed significantly worse on the HVOT. Among German-speaking neurological patients, the HVOT performance did not depend heavily on language or naming skills (Merten, 2005). Naming impairment did not contribute to performance on the HVOT among subjects with subcortical vascular dementia (Paul et al., 2001). Overall, these findings lend a strong support for test's construct validity as a measure of visual perceptual organization with confrontational naming ability playing a small but significant role in test performance.

Wechsler Memory Scale - Third Edition

The Wechsler Memory Scale - Third Edition™ (WMS-III; Wechsler, 1997) instrument (Psychological Corporation, San Antonio, TX) provides measures of various aspects of memory function (Spreen & Strauss, 1998). The following subtests were used in this battery: Logical Memory I, Logical Memory II, Logical Memory Recognition, Visual Reproduction I, Visual Reproduction II, Visual Reproduction Recognition, Letter-Number Sequencing, Mental Control, Digit Span, and Spatial Span.

Logical Memory

Logical Memory is a measure of episodic memory. Logical Memory I (LM I) involves the examiner reading two short stories, stopping after each to test individuals immediate recall. The second story is read twice, giving individual two learning trials. LM I is a measure of immediate recall.

Following a 30-minute delay, Logical Memory II (LM II) subtest is introduced to measure delayed recall of both stories. There is a strong association between LM II and other learning tests (Woodard, Goldstein, Roberts, & McGuire, 1999). Woodard et al. (1999) concluded that LM II is the "purest" measure of episodic memory because of its least amount of overlap with non-episodic memory tests. Logical Memory Recognition (LM Recognition) task follows immediately after LM II to assess storage and retrieval. The recognition task has a cued recall format, and contains 30 yes-no questions.

Visual Reproduction

Visual Reproduction subtests were intended to provide a measure of visual memory, however Haut et al. (1994) warned that visual perception deficits may confound the results of these subtests. The effect of constructional skills on Visual Reproduction test performance has been demonstrated by factor analytical studies (e.g., Larrabee & Curtiss, 1995) and clinical group comparison (Gfeller, Meldrum, & Jacobi, 1995).

Visual Reproduction I (VR I) was designed to measure immediate recall for a visuo-spatial stimuli (Lezak et al., 2004). Five geometric designs are presented in sequence, for 10 seconds each. After each design is presented, an individual is asked to draw the design from memory. Although VR I was designed to measure immediate non-verbal memory, numerous studies found VR I to be more related to construction and performance abilities, rather than memory (Woodard et al., 1996; Larrabee, Kane, & Schuck, 1983; Larrabee, Kane, Schuck, & Francis, 1985; Ryan, Rosenberg, & Heilbronner, 1984). Smith, Malec, & Ivnik (1992) conducted a confirmatory factor analysis of WMS-R, WAIS-R, and RAVLT, and concluded that Visual Reproduction I may relate more to visuoperceptual abilities rather than to memory.

Visual Reproduction II (VR II) is performed 30 minutes later, to assess delayed visuospatial memory. An examinee is asked draw the designs learned in the immediate condition. The Visual Reproduction Recognition (VR Recognition) subtest is a visual cued recall task. Following VR II, an examinee is presented with a series of 48 designs, one at a time, and asked to identify the designs learned in the immediate condition.

Letter-Number Sequencing

Letter-Number Sequencing (LNS) is a new WMS-III and Wechsler Adult Intelligence Scale - Third Edition™ (WAIS-III; Wechsler, 1997) instrument (Psychological Corporation, San Antonio, TX) subtest. It is a measure of working memory that uses auditory stimuli (Wechsler). On WAIS-III, the LNS, Arithmetic and Digit Span form the Working Memory index. Lezak et al. (2004) argued that the LNS is a more sensitive measure of working memory than other WAIS-III subtests. On the WMS-III, scores from the LNS and Spatial Span contribute to the Working Memory index that indicates "the capacity to remember and manipulate both visually and orally presented information in short-term memory storage" (Wechsler, p. 7).

The test presents an examinee with a sequence of alternating letters and numbers, and askes to repeat the sequence by saying the numbers first in the ascending order, followed by the letters in the alphabetical order. The sequence increases in length from two to eight elements. The examinee needs to hold the letter-number sequence in a working memory, manipulate them into a new order, and repeat them in a new sequence (Groth-Marnat, Gallagher, Hale, & Kaplan, 2000). The test performance demonstrates attention, concentration, sequencing ability, and working memory (Groth-Marnat et al., 2000).

Reviewed literature shows that the LNS consistently loads on a Freedom from Distractibility factor, along with Arithmetic and Digit Span subtests of Wechsler scales (Lezak et al., 2004). The test significantly correlates with other measures of attention and working memory, Digits Forward, Digits Backward, Symbol Search, and Arithmetic (Crowe, 2000).

Mental Control

Mental Control involves performing "overlearned tasks such as saying the alphabet and novel multi-skill tasks such as alternating between counting by sixes and saying the days of the week" (Wechsler, 1997, p. 5). The test intends to measure ability to retrieve overlearned information and to mentally manipulate that information (Wechsler). The first four items of the test appear to tap into the "overlearned" information, such as counting from 1 to 20, reciting the alphabet, saying days of the week in order, and saying months of the years in order. The last four items require performance of novel tasks, such as counting backwards from 20 to 1, saying days of the week backward, saying months backward, and alternating between counting by sixes and saying the days of the week. Whereas the first four items rely on automatic processing of familiar tasks, the four later items involve executive function. Diesfeldt (2004) stated that naming days of the week and months of the year backwards is an executive function task.

Overall, Mental Control is considered to be a measure of attention (e.g., Roth et al., 1990). Factor analysis conducted on tests of attention, information processing, verbal and visual memory found the Mental Control, Digit Span and the Paced Auditory Serial Addition Test (PASAT) to load on a factor that authors defined as attention and information processing (Larrabee & Curtiss, 1995). The WMS-R Mental Control factored with the WAIS-R Digit Span, Arithmetic, Speech Sounds Perception Test and Rhythm Test of the Halstead-Reitan Battery on the Attention and Concentration factor (Leonberger, Nicks, Larrabee, & Goldfader, 1992). In another study, Mental Control was correlated with Behavioral Dyscontrol Scale, and concluded to be a measure of executive function (Diesfeldt, 2004).

Digit Span

The Digit Span measures span of immediate verbal recall, and is primarily a measure of attention (Lezak et al., 2004). The test loaded on Attention and Concentration factor, alone with the Rhythm Test of the Hastead-Reitan Neuropsychological Test Battery (HRNB), the Mental Control subtest of the WMS-R, the Arithmetic subtest of the WAIS-R, and the Speech Sounds Perception Test of the HRNB (Leonberger et al., 1992). The two components of this test are Digits Forward and Digits Backward. In the Digits Forward, the examiner reads a series of digits at the rate of one per second and asks the examiner to say the digits in the same order (Wechsler). In the Digits Backward, the examiner reads a series of digits and asks the examiner to say the digits in the reverse order. Both test components depend on auditory attention and short-term retention capacity (Lezak et al.). Lezak et al. encourages interpreting the two test scores separately, rather than using a less meaningful total score.

The Digits Forward is primarily a measure of attention (Lezak et al., 2004). Several researchers argued that the Digits Forward assessed attention instead of memory, and factored on an attention-concentration or freedom-from-distractability factor (e.g., Fowler et al., 1987; Kaufman, McLean, & Reynolds, 1991; Prigatano, 1978).

The Digits Backward is a test of mental tracking or working memory that requires storing several bits of data and mentally manipulating them (Lezak et al., 2004). The Digits Backward is more of a memory test, compared to a more passive Digits Forward. It involves use of the working memory (Banken, 1985; Black, 1986), and has been linked to executive function (Baddeley et al., 1992).

Spatial Span

In Spatial Span a series of spatial patterns is shown using a three-dimensional board. For Spatial Span Forward, the examiner points to blocks in a specific sequence at a rate of one block per second, and the examinee points to the same blocks in the same order. For the Spatial Span Backward, the examiner points to blocks in a specific sequence, and the examinee needs to point to the blocks in the reverse order. The test measures individual's ability to hold a visual-spatial sequence in working memory and reproduce the sequence (Wechsler, 1997).

Spatial Span loads on the primary index of Working Memory, alone with the LNS subtest on WMS-III (Wechsler, 1997). These two tests intend to measure capacity to remember and manipulate both visually and orally presented information in short-term memory storage (Wechsler).

The Consortium to Establish a Registry for Alzheimer's Disease

The Consortium to Establish a Registry for Alzheimer's Disease (CERAD) has developed as standardized neuropsychological battery to examine dementia and follow its progression (Morris et al., 1989). The battery includes seven subtests - Verbal Fluency, the Modified Boston Naming Test, the Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975), Word List Memory Task, Constructional Praxis Test, Word List Recall Task, and Word List Recognition Task.

Verbal Fluency

On the Verbal Fluency task, participants are asked to say as many items as they can that belong in the category of Animals within a one-minute period. The score is the total number of items. Impaired verbal fluency accompanies aphasia disorders, frontal lobe damage, dementia. Performance on category fluency tests has been used an index of frontal lobe function (Baldo & Shimamura, 1998). The role of frontal lobes in the verbal fluency task has been confirmed by several neuroimaging studies (Brannen et al., 2001; Frith et al., 1991; Parks et al., 1988).

The test requires maintaining a task set, generating multiple response alternatives, keeping generated responses in working memory to avoid repetitions and using retrieval strategy (Diesfeldt, 2004). Effective performance on the test involves organizing and clustering words on some principle (e.g., domestic animals, wild animals, birds, etc.) and switching to the next cluster when one cluster is exhausted (Lezak et al., 2004). Switching involves cognitive flexibility and is an effortful task (Troyer et al., 1998). Clustering is related to temporal lobe functioning, whereas frontal lobes mediate switching and strategic control of memory processes (Troyer et al.).

Impairment of verbal fluency in patients with frontal lobe lesions was suggested to be due to failure to develop retrieval strategies (Baldo & Shimamura, 1998). It was also argued that perseveration, impaired ability to shift attention and switch strategy account for poor performance on the task in these patients (Troyer et al., 1998; Troyer, Moscovitch, & Winocur, 1997). Baldo, Shimamura, Delis, Kramer and Kaplan (2001) suggested that patients with frontal lobe lesions fail to generate and/or utilize internally derived strategies.

Woodard et al. (1996) refer to Animal Fluency as a measure of semantic memory retrieval and found this neuropsychological measure to load on the Memory factor in a sample of individuals with Alzheimer's disease, alone with LM I, LM II, VR II and Digit Span. Woodard, Goldstein, Roberts and McGuire (1999) found a significant correlation between Animal Fluency and multiple measures of memory (LM I, LM II, CVLT, VR I and VR II) among geriatric patients presenting with memory complaints.

Normal aging is associated with decline in semantic (category) fluencies, but not phonological (letter) fluency (e.g., Crossley, D'Arcy & Rawson, 1997). Alzheimer's Disease (AD) is associated with impairments on both category and letter fluency, but they show relatively greater impairment on category fluency (e.g., Fama et al., 1998; Monsch et al., 1994). Monsch et al. (1994) explained this difference with dependence of performance on category fluency on the intact semantic knowledge. In the Animal fluency test this implies knowledge of what constitutes the concept of 'animal' (animal characteristics). The neuropathology of medial temporal and cortical areas in AD is underlying breakdown in semantic knowledge (Monsch et al.). It was argued that impairments on fluency tasks in patients with AD are due to some combination of retrieval and semantic problems (Monsch et al.).

Boston Naming Test

Boston Naming Test (BNT) was designed to assess the ability to name pictured objects (Goodglass & Kaplan, 1983). The BNT is a test of confrontation naming and assesses the ability to retrieve words and vocabulary level (Lezak et al. et al., 2004). It was designed to identify aphasic patients with dysnomia, but has proven to be sensitive to a variety of conditions, including vascular dementia, Alzheimer's disease, multiple sclerosis, and traumatic brain damage (Lezak et al.). The Modified Boston Naming Test consists of 15-item picture set with five words each of low, medium, and high frequency of occurrence from the original test (Kaplan, Goodglass, & Weintraub, 1983).

Word List Memory

Word List Memory Task is designed to measure memory and verbal learning (Lezak et al., 2004). It includes a list of ten unrelated words that are printed in large letters on cards and are presented visually at a rate of one every 2 seconds. An examinee is given up to 90 seconds to recall all ten words. The same words are presented in a different order on the following two trials. Recall follows each trial. An examiner records correctly recalled words and any intrusion words. Word List Memory Task score is derived by adding total number of words recalled over the three trials. It is a measure of immediate recall. Word List Recall follows after a brief 3 to 5 minute delay during which a non-verbal Constructional Praxis task is administered. An examiner tests delayed free recall by asking the examinee to recall as many words as possible. Word List Recognition Task assesses storage and retrieval. It involves a recognition trial in which ten unrelated distractor words are intermixed with the original ten words. The person is asked to say "Yes" is the shown word is the one he/she saw earlier, and "No" if it is not.

Among subjects with probable Alzeimer's disease, the CERAD word list task was found to be a good alternative to a more complex and lengthy California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987), a well-established measure of learning and memory in clinical neuropsychology (Kaltreider et al., 2000). One of the key characteristics of AD is rapid forgetting of newly learned material (Butters et al., 1988; Welsh et al., 1992). Word List Recall was found to be the most sensitive measure among the CERAD subtests to discriminate Alzheimer's disease from normal aging controls (Welsh et al., 1991; Welsh et al., 1992).

Constructional Praxis

Constructional Praxis is a measure of visuospatial-visuomotor abilities (Rosen, Mohs, & Davis, 1984). Constructional Praxis Test instructs individuals to copy four geometric figures (a circle, a diamond, two intersecting rectangles, and a cube) that are presented one at a time.

Behavioral Dyscontrol Scale

Behavioral Dyscontrol Scale (BDS) was first published by Kaye, Grigsby, Robbins and Korzun in 1990, and was based in Alexander Luria's theory of frontal lobe functioning. Behavioral Dyscontrol Scale 2 (BDS-2) was published in 1992 by Grigsby, Kaye and Busenbark. It was originally designed as a brief measure of executive functioning in older adults to predict ability to independently perform purposeful activity, such as activities of daily living. Multiple studies confirmed instrument's predictive ability of functional independence among community-dwelling older people (Grigsby, Kaye, Baxter, Shetterly, & Hamman, 1998) and orthopedic and stroke rehabilitation patients (Grigsby, Kaye, Eilertsen, & Kramer, 2000; Grigsby, Kaye, Kowalsky, & Kramer, 2002; Kaye et al., 1990; Suchy et al., 1997).

The BDS-2 consists of nine items. Seven of the items measure ability to control voluntary motor activity. Among them, two items involve alternating between right and left hand single and double tapping in a series, two require performance of go no-go tasks, two require learning of new hand movements, and one requires copying hand movements while inhibiting mirroring. One item requires sequencing numbers and letters of the alphabet, and measures working memory and cognitive flexibility. The last item is a measure of insight, and evaluates person's ability to monitor and assess own performance on the test. Despite such seeming heterogeneity of items, all nine items were found to measure the same ability to regulate behavior (Diesfeldt, 2004).

It is one of the executive measures that require abstract thinking, planning, sequencing, initiating, monitoring and stopping complex behavior (Diesfeldt, 2004). Exploratory factor analysis conducted by test developers identified three factors: ability to use an intention to guide behavior, ability to use feedback, and capacity for inhibition (Grigsby, Kaye, & Robbins, 1992). This factor structures was confirmed by a confirmatory factor analysis (Ecklund-Johnson, Miller, & Sweet, 2004). The test is strongly correlated with other measures of executive function, such as the Expanded Mental Control Test, Category Fluency and the alternating graphical sequences (Diesfeldt). The BDS is related to other measures of executive function, the Stroop Color Word Test and a modification of the Wisconsin Card Sorting Test™ instrument (Wells Print & Digital Services, Inc., Madison, WI) in geriatric population (Suchy, Blint, & Osmon, 1997). Though the BDS demonstrates good convergent validity for a theoretical construct of executive function, Diesfeldt argued that its high correlation with tests measuring the construct of episodic memory questions instruments utility as an executive-specific measure.

Trailmaking Test

Trailmaking Test (TMT) comes from the Army Individual Test Battery (1944; Lezak et al., 2004). It's a test of speed, attention, sequencing, mental flexibility, visual search, and motor function (Spreen & Strauss, 1998).

Part A asks patients to draw a line that connects circles with numbers from 1 to 25 in order. The amount of time needed for completion of the task was used for the analysis.
TMT A is a measure of general cognitive efficiency and processing speed. It is a test of visual search, attention, and motor function.

Part B is more demanding than Part A, as it requires the ability to shift attention between two sets (letters and numbers). Patients need to draw a line that connects numbers and letters in an alternating sequence (i.e., A-1, B-2, C-3, etc.). The amount of time needed for completion of the task was used for the analysis. Shifting between letters and numbers requires mental flexibility and more effortful executive processing (Lezak et al., 2004). Part B is related for frontal lobe integrity. Part B also contains more visual interference, and has higher demands for visual-perceptual processing and motor speed than Part A (Gaudino, Geisler, & Squires, 1995; Woodruff et al., 1995) Heilbronner et al. (1991) found a moderate correlation between scores on Part A and Part B, suggesting that two tests measure a different construct.

Clock Drawing Test

The purpose of the Clock Drawing Test (CDT) is to screen for visuospatial and constructional impairments (Spreen & Strauss, 1998). It is commonly used to screen for dementia. The test requires visuospatial, constructional and higher-order cognitive abilities (Spreen & Strauss). The patient is provided with blank piece of paper, and is asked to draw the face of a clock, put the numbers in the correct positions, and draw in the hands at ten minutes after eleven. Freedman, Kaplan, Delis, and Morris (1994) suggested that these time setting instructions might be better for assessment of frontal lobe function. A four-point scoring method was used. Clock drawings were rated for accuracy of the circle, presence of numbers, spacing between numbers, and accuracy of position of the two hands of the clock.

Successful performance on the test requires ability to form a visuospatial representation of a clock, and perceptual-motor ability to draw that representation (Lacks, 2000). The CDT is correlated with other tests of visuoconstructional ability, such as the copy task on the Rey-Osterreith test, and Block Design (Freedman et al., 1994). Mendez, Ada and Underwood (1992) found strong correlations with the Rey Complex Figure and the Symbol Digits Modalities Test. The CDT is also sensitive to executive function impairments (Lezak et al., 2004). The CDT was found to be correlated with tests of executive functions, such as Trailmaking Test and Block Design (Libon, Swenson, Barnoski, & Sands, 1993). In healthy older adults the CDT correlated with neuropsychological measures of executive function and visuoconstruction, specifically Block Design and the HVOT (Libon et al.).

The test successfully classified normally aging individuals, and patients with Alzheimer's disease, multi-infarct dementia, and depression (Tuokko, Hadjistavropoulos, Miller, & Beattie, 1992; Wolf-Klein, Silverstone, Levy, & Brod, 1989). Patients with Alzheimer's disease perform worse on the test, compared to healthy controls, and performance was significantly related to gray matter volume of the right anterior-superior temporal lobe (Cahn-Weiner et al., 1999). The number of neurons in the hippocampus and the parahippocampal gyrus is related to clock drawing ability (Forstl, Burns, Levy, & Cairns, 1993). However, the CDT doesn't discriminate between Alzheimer's dementia and vascular dementia (Barr, Benedict, Tune, & Brandt, 1992; Libon et al., 1996).

The Hypothesized Model

Based on literature reviewed, the following six cognitive domain factors were constructed by combining related cognitive tests: verbal memory, visual memory, working memory, attention-concentration, executive functions, and visuospatial abilities. The assignment of a test to a cognitive domain factor was consistent with the generally accepted classification system used in neuropsychological testing, reviewed empirical and theoretical evidence. The proposed six-factor model tested was as follows: (1) Verbal Memory factor: LM I, LM II, LM Recognition, Word List Memory, Word List Recall, Word List Recognition, and the BNT; (2) Visual Memory factor: VR II, and VR Recognition; (3) Working Memory factor: Digits Backward, Spatial Span, the LNS, Mental Control (Items 5-8), and Trailmaking B; (4) Attention-

Concentration factor: Digits Forward, Trailmaking A, and Mental Control (Items 1-4); (5) Executive Functions factor: the BDS-2, Verbal Fluency, and the CDT; (6) Visuospatial Abilities factor: the HVOT, VR I, and Constructional Praxis.

METHOD

Participants

A total of 114 participants (41 men and 73 women) with a mean age of 78.77 years (*SD* = 7.03), and mean Mini-Mental Status Exam (MMSE) score of 24.69 (*SD* = 3.459) were selected for the study. Thirty four participants received a diagnosis of Alzheimer's dementia, 31 participants received a diagnosis of vascular dementia, 22 participants were diagnosed with cognitive disorder not otherwise specified, 18 participants were diagnosed with dementia due to multiple etiologies, Alzheimer's type and vascular dementia, and 9 participants were diagnosed with dementia of the "other" type. The later category predominantly included participants with Parkinson's dementia. Five participants were missing data on the diagnosis severity. Out of the 109 available records, 68 individuals had "mild severity", 10 individuals had "mild to moderate" severity, 28 individuals had "moderate" severity, 2 had "moderate to severe" severity, and 1 had "severe" severity.

Procedure

The analysis was performed using a neurocognitive database of patients from the geriatrics clinic at the University of North Texas Health Science Center who presented with cognitive deficits and were referred for a neurocognitive evaluation. Data in the database was collected from 2001 through 2006. Geriatric neurocognitive evaluations were conducted by a licensed psychologist, post-doctoral fellows or trained student clinicians and assessed multiple domains of cognitive ability. Evaluations required approximately 2 hours to complete, and included clinical interview, typically completed n collaboration with patient's caregiver, and a comprehensive battery of neurocognitive tests.

The diagnosis type and severity was based on the analysis of the pattern of performance on the neuropsychological battery, clinical interview, caregiver's report of functional ability, review of medical history, and clinical observations. Global cognitive functioning was measured by the MMSE subtest of the CERAD.

RESULTS

Assumptions

Prior to analysis, all variables were examined through various SPSS™ analytical software (Nie, Norman H., Chicago, IL) programs for accuracy of data entry, missing values, univariate and multivariate outliers. Out of 349 original cases in the database, 118 complete cases were selected for the analysis that contained scores for all 23 neuropsychological tests used in the analysis. There were no missing data on neuropsychological test scores in the set.

Normality of the observed variables was assessed through examination of histograms. Scores on Trailmaking A were highly kurtotic, with a standardized kurtosis of 4.09. However, scores on the neuropsychological tests in this clinical population were not expected to be normally distributed, hence no score transformation was performed to preserve original characteristics of this clinical sample. No multivariate outliers were identified using the criterion of Mahalonobis' distance at $p < .001$, χ^2 (23) = 49.73. Ten cases were identified as univariate outliers. Eight participants were found to have an extremely high score ($z > 3.29$) on one of the neuropsychological tests, and two participants were found to have extremely high scores ($z > 3.29$) on two of the neuropsychological test. All univariate outliers were retained for the analysis. Four cases that received no cognitive diagnosis were deleted, leaving 114 cases for further analysis. Descriptive statistics for individual tests for this sample are presented in Table 1.

Confirmatory Factor Analysis

A confirmatory factor analysis was performed through EQS 6.1 for Windows™ structural equation modeling software (Multivariate Software, Inc., www.mvsoft.com) on the scores from 23 tests of the neuropsychological battery to test the proposed six-factor model of cognitive functioning. Model fit was assessed by the chi-square goodness of fit statistics, the goodness of fit index (GFI), the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). The ratio of chi-square statistic to the associated degrees of freedom was also used for the assessment of the fit. The ratio is an index of model fit corrected for the complexity of the model (Loewenstein et al., 2001). Generally, the ratio of chi-square to the degrees of freedom less than 2 indicates a good-fitting model (Tabachnik & Fidell). Significant chi-square test of goodness of fit implies a significantly poor model fit (Tabachnik & Fidell). The CFI is a good estimator of model fit in small samples, and values greater than .95 indicate a good model fit (Tabachnik & Fidell). The GFI is an index of absolute fit, and provides an index of the relative amount of the variance accounted for by the model. The GFI values greater than .85 indicate an acceptable fit of a model (Loewenstein et al.). The RMSEA is based on the analysis of the residuals, and values less than .05 suggest a good model fit (Brown & Cudeck, 1993).

Maximum likelihood estimation was employed to estimate the six-factor model. The results of the various fit indices were consistent, and lead to the conclusion of a poor fit of the model to data, with a GFI of .608, a CFI of .555, a RMSEA of .143, and a chi-square to degree of freedom ratio of 3.3. Overall chi-square value of 739.97 was significant, suggesting poor fit.

Exploratory Factor Analysis

An exploratory factor analysis (EFA) was used to find flaws in the proposed model using the SPSS analytical software. EFA intended to examine the latent structure of the participant's neuropsychological test scores, to discover the optimal number of factors in the data, and to determine which tests form coherent factors that are relatively independent of each other.

Principle components extraction unrotated factor solution was used in an initial run to estimate the number of factors from eigen values. Five factors (eigen values larger than 1) were extracted that explained 62.13% of the total variance. Eigen values for the first two factors were larger than two. The scree plot of eigen values plotted against factors visually suggested breaks between 3 and 5 factors, and is shown in Figure 1. All five factors were retained for interpretation to increase model's fit and the percent of variance explained by the factor solution.

After extraction, direct oblimin rotation technique (oblique type) was used to simplify factors by minimizing cross products of loadings. Oblique rotation rather than orthogonal rotation was chosen due to the number of significant correlations among variables so as not to distort the resultant factor structure by forcing independence of factors. Delta was set at zero to allow solutions to be fairly highly correlated. Loadings of .45 or greater were used as the cutoff criteria for interpretation of factors. The factor loadings for each neuropsychological test on each of the retained factors are presented in Table 2.

The resulting solution did not achieve simple structure, as most test scores had significant loadings on several factors. Factor 1 had highest loadings on the LM I, LM II, LM Recognition, Word List Memory, Word List Recall, Word List Recognition, VR I, VR II, VR Recognition, and the LNS, and was labeled Memory. Factor 2 was strongly associated with tests involving executive functioning, marked by high loadings on the Mental Control (Items 1-4 and Items 5-8), the BDS-2, and Spatial Span, and was named Executive Control. Factor 3 was marked by high loadings on the Digits Span Forward and Backward, and was named Attention. Factor 4 received loadings from the CDT, the HVOT, and Constructional Praxis. This fourth factor was labeled Visuospatial Abilities. Factor 5 received loadings of Trailmaking A, Trailmaking B, with smaller contributions of the BNT and Verbal Fluency test. This last factor was named Cognitive Flexibility.

Five factors had two to eleven variable loadings each. The Memory factor received highest loadings from tests designed to measure verbal and visual memory, and a test of working memory (i.e., the LNS). All three Visual Reproduction subtests cross-loaded on multiple factors, with highest cross-loadings on factor 4, Visual Abilities. VR I significantly correlated with factor 2 (Executive Control; r = .45) and factor 4 (Visuospatial Abilities; r = .56). VR II and VR Recognition also significantly correlated with factor 4 (Visuospatial Abilities), r = .45 and r = .50, respectively. Word List Recognition subtest also had high cross-loadings on the Visuospatial Abilities factor, r = .51. Table 3 demonstrates interfactor correlations after oblimin rotation. The interfactor correlations between factors ranged from .14 (Memory factor and Executive Control factor ; $p < .05$) to -.39 (between Memory factor and Visuospatial Abilities factor; $p < .05$). High number of cross-loading items between Memory and Visuospatial Abilities factors is reflected in the high interfactor correlation.

Factor 2, Executive Control received highest loadings from Mental Control (Items 1-4 and Items 5-8), the BDS-2, and Spatial Span. Mental Control (Items 1-4) and Mental Control (Items 5-8) were significantly correlated, r = .43. Trailmaking B had its second highest loading on this factor.

Factor 3, Attention, received loadings only from two variables, Digit Span Forward and Digits Span Backward, suggesting that the factor may be poorly defined. However, based on the matrix of correlations between variables, Digit Span Forward and Digit Span Backward are significantly correlated with each other, r = .45, and are relatively uncorrelated with other variables, with the only other moderate correlation existing between Digit Span backward and Mental Control (Items 5-8), r = .42. Both variables were relatively pure measures, loading heavily on one factor. This suggests that factor 3 is moderately reliable, but needs to be interpreted with caution. The Attention factor received cross-loadings from the LNS (r = .44) and Mental Control (Items 5-8; r = .51). These tests are measures of complex attention, or working memory, and require a person to remember and to manipulate presented information in short-term memory.

Factor 4, Visuospatial Abilities, had high loadings from the CDT, the HVOT, and the BNT. In addition, Trailmaking A, Word List Recognition, VR I, VR II, and VR Recognition had their second highest loadings on this factor.

Finally, Factor 5 labeled Cognitive Flexibility received highest loadings from Trailmaking A, Trailmaking B, Verbal Fluency, and the BNT. Significant correlations were noted between Trailmaking A and Trailmaking B (r = .50), Trailmaking A and the HVOT (r = -.51), the BNT and the HVOT (r = .40). Other high loading on this factor came from the HVOT, and Word List Learning.

DISCUSSION

The aim of the study was to evaluate the factor structure of the neuropsychological battery of tests in the geriatric sample with the confirmatory factor analysis. The proposed six-factor model of cognitive functioning (Verbal Memory, Visual Memory, Working Memory, Attention-Concentration, Executive Functions, and Visuospatial Abilities factors) that was based on reviewed research has not been supported by the confirmatory factor analysis. Further exploratory factor analysis supported a five-factor model of cognition. Factor pattern of the 23 tests supported the following five dimensions: Memory, Executive Control, Attention, Visuospatial Abilities, and Cognitive Flexibility.

The current study found no evidence of separate verbal and visual memory components. Tests that were intended to measure visual memory, VR I, VR II, and VR Recognition loaded on the Memory factor, alone with the tests measuring verbal memory, the three WMS-III Logical Memory subtests and the three CERAD Word List learning subtests. The visual memory subtests of the WMS-III to a lesser degree, but strongly correlated with the factor labeled Visual Abilities that received highest loadings from tests requiring visuospatial skills, such as the CDT, the HVOT, and Constructional Praxis. This suggests that performance on all three Visual Reproduction subtests partially depends on visuospatial processing. Overall, this finding is consistent with prior research showing that Visual Reproduction subtests showed a stronger association with memory than with visuospatial abilities (e.g., Larrabee et al., 1985; Leonberger, Nicks, Larrabee & Goldfader, 1992). The LNS, which is most commonly referred to as a measure of working memory, loaded highly on the factor of Memory, and to a lesser degree on the Attention factor. One hypothesis is that impairment in working memory underlies impaired retrieval processes in the geriatric population presenting with memory deficits. Diminished encoding at the onset of the memory task may be responsible for deficits in retrieval later.

The Executive Control factor received loadings from the Mental Control (Items 1-4 and Items 5-8), the BDS-2, and Spatial Span. Although the first four items on Mental Control rely more on automatic information processing, while the last four items involve executive function (Diesfeldt, 2004), both loaded on the same factor in this analysis, and moderately correlated with each other. All three tests rely on mental manipulation for successful completion of the task, and have been discussed as measures of frontal lobe function.

The Attention factor received highest loadings from Digit Span Forward and Digit Span Backward, with smaller contributions of Mental Control (Items 5-8) and the LNS. A moderate correlation between the two subtests of the Digit Span suggests they measure similar, but different cognitive functions. Both subtests heavily loaded on the Attention factor, with minimum cross-loadings on other factors, suggesting they were relatively pure measures. Surprisingly, the other two tests of simple attention, Mental Control (Items 1-4) and Trailmaking A did not significantly load on this factor. Observed weak correlations between the Digit Span subtests, Trailmaking A and Mental Control (Items 1-4) suggest that the Digit Span subtest is a measure of attention that is different from Trailmaking A that relies on a visual and motor function, and Mental Control (Items 1-4) relying on retrieval of overlearned information. On the other hand, the two tests of complex attention, Mental Control (Items 5-8) and the LNS significantly correlated with the Attention factor. These tests are measures of complex attention, or working memory, similar to the Digit Span Backward subtest, and require a person to remember and to manipulate presented information in short-term memory. Thus, the derived

Attention factor predominantly reflects complex attention, and to a lesser degree simple attention.

The proposed Visuospatial Abilities factor was partially supported in this analysis. The Visuospatial Abilities factor included two of the three tests suggested by the theoretical analysis, specifically the HVOT, and Constructional Praxis. The factor received high loadings from the CDT, supporting validity of the test as a measure of visuospatial and constructional abilities (Freedman et al., 1994; Spreen & Strauss, 1998). The CDT and Constructional Praxis both require constructional visuomotor abilities, whereas the HVOT requires visuoconstructional abilities, including ordering, mental manipulation, and sequencing. VR I was expected to load on the Visuospatial Abilities factor. This subtest loaded highest on the Memory factor, and to a lesser degree on Visuospatial Abilities and Executive Control factors. This suggests that VR I measures several cognitive functions, and is not a "pure" measure of memory or visuospatial abilities. The Visuospatial Abilities factor also received high loadings from Word List Recognition subtest of the CERAD, reflecting the visual component of this written word recognition test.

The last factor in the analysis, labeled Cognitive Flexibility encompasses four different test measures, Trailmaking A, Trailmaking B, the BNT and Verbal Fluency. The HVOT had high correlations with this factor. Although the factor does not appear to be homogeneous, it included tasks requiring higher executive functioning, with frontal lobe functioning implemented in performance on all four tests, Trailmaking A, Trailmaking B, Verbal Fluency, and the BNT (Lezak et al., 2004). Majority of tests on this factor require concurrent manipulation of information, the ability known as cognitive flexibility. Cognitive flexibility requires an individual to rapidly assess, and appropriately respond to changing environmental demands, and can be conceptualized as "the opposite of perserveration." It involves switching mental set in response to changing stimuli, while maintaining the set of original rules, and/or one's previous responses. In Verbal Fluency, one must maintain a task set, keep generated responses in working memory to avoid repetition, organize words into clusters, and switch from one cluster to the next. The list of available responses constantly narrows, and depends on individual's previous responses. Trailmaking B requires a person to continuously switch mental set by alternating numbers and letters, while remembering the previous sequence and rules. Trailmaking A does not involve shifting between categories as Trailmaking B does, however, each response is unpredictable, as each time one needs to scan the new set of available choices, reassess direction of the next move, and respond accordingly. As the list of possible choices constantly narrows, the environmental demands change as well. On the BNT, one must respond appropriately to the changing stimuli. Similarly, mental set switches with each new item presented on the HVOT. The constantly changing stimuli are independent of each other, and demand one to constantly reevaluate newly available options, and respond appropriately. A person must also maintain the rules of the test of putting picture fragments together, and inhibit the inclination to interpret one piece of the picture.

There are several limitations to the current findings. The current sample consisted of a heterogeneous population of geriatric cognitively impaired individuals. Our sample included individuals with mild to severe cognitive deficits, and etiologically different cognitive impairments. It is reasonable to expect different patterns of cognitive impairment in individuals with Alzheimer's dementia and vascular dementia. If a larger and a more homogeneous sample of patients (e.g., patients with Alzheimer's dementia) were studied, the factor structure might differ from that found in this study. Also, the determination of the number of factors to retain is arbitrary, and based on statistical and graphic outputs, and no agreement exists between statisticians regarding the decision method (Tabachnik & Fidell, 2001). Although we chose a five-factor solution, other factor solutions could have been chosen. The five-factor model was chosen with the goal of maximizing the percent of variance explained by the factor solution, and attaining a more clinically meaningful model that can separate deficiencies into multiple cognitive domains. If greater value was placed on parsimony, and a smaller number of factors were retained, the attained solution would have been different.

In summary, the original proposed six-factor model did not fit the data. Exploratory analysis yielded a five-factor model with different factor loadings than the proposed theory-based model. We interpreted these factors as representing memory, executive functions, attention, visuospatial abilities, and cognitive flexibility. No evidence was found for a separate visual memory factor, and rather a general memory factor appeared to emerge that included both visual and verbal memory.

Table 1

Mean Scores and Standard Deviations on Individual Measures

Measure	Mean	Standard Deviation
Wechsler Memory Scale - Third Edition		
Logical Memory I	21.33	9.61
Logical Memory II	7.54	7.95
Logical Memory Recognition	19.81	4.08
Visual Reproduction I	42.54	17.67
Visual Reproduction II	13.44	16.36
Visual Reproduction Recognition	35.08	6.2
Digits Span Forward	8.75	1.99
Digits Span Backward	4.75	1.71
Letter-Number Sequencing	5.94	2.84
Mental Control (Items 1-4)	9.24	1.98
Mental Control (Items 5-8)	6.13	3.05
Spatial Span		
Consortium to Establish a Registry for Alzheimer's Disease		
Word List Memory Task	14.34	4.37
Word List Recall Task	2.75	2.64
Word List Recognition	7.26	2.87
Verbal Fluency	12.94	4.35
Boston Naming Test	13.25	2.00
Constructional Praxis	8.57	1.82
Behavioral Dyscontrol Scale - 2	14.27	4.31
Trail Making Test (Part A)	80.55	58.72
Trail Making Test (Part B)	219.96	83.05
Clock Drawing Test	3.07	.88
Hooper Visual Organization Test	19.06	5.35

Table 2

Factor Structure Matrix After Oblique Rotation With Kaiser Normalization

	Factors				
	Memory	Executive Control	Attention	Visuospatial Abilities	Cognitive Flexibility
LM I	**.83**	.13	.26	.27	-.38
LM II	**.91**	.11	.10	.29	-.22
LM Recog	**.79**	.14	.15	.38	-.19
WL	**.79**	.07	.24	.18	-.51
WL Recal	**.88**	.40	.03	.39	-.21
WL Recog	**.62**	-.29	.07	.51	.04
VR I	**.71**	.45	.16	.56	-.40
VR II	**.80**	.35	.12	.45	-.19
VR Recog	**.51**	.38	.09	.50	-.29
LNS	**.56**	.39	.44	.32	-.31
MC 1-4	.16	**.55**	.33	.19	-.38
MC 5-8	.44	**.57**	.51	.36	-.35
BDS-2	.26	**.64**	.19	.44	-.32
SS	.16	**.67**	.22	.24	-.14
DS Back	.16	.25	**.79**	.17	-.10
DS For	-.03	.10	**.84**	.10	-.10
CDT	.26	.28	.20	**.83**	-.25
HVOT	.49	.22	.31	**.66**	-.51
Praxis	.32	.26	.22	**.77**	-.33
BNT	.44	-.01	.35	.36	**-.47**
TMT-A	-.26	-.17	-.26	-.48	**.77**
TMT-B	-.22	-.39	-.07	-.27	**.76**
Fluency	.48	.18	.09	.19	**-.52**

Table 3

Interfactor Correlation Matrix After Oblimin Rotation

Factor	Memory	Executive Control	Attention	Visuospatial Abilities	Cognitive Flexibility
Memory	1.00				
Executive Functions	.14	1.00			
Attention	.16	.19	1.00		
Visuospatial Abilities	.39	.21	.19	1.00	
Cognitive Flexibility	-.29	-.23	-.21	-.25	1.00

Table 4

Correlations Among the Variables

	LM I	LM II	LM Recog	WL	WL Recal	WL Recog	BNT	VR II	VR Recog	DS Back	LNS	MC 5-8	TMT B	DS For	TMT A	MC 1-4
LM I	1.00															
LM II	.80	1.00														
LM Recog	.64	.71	1.00													
WL	.66	.64	.57	1.00												
WL Recal	.64	.76	.63	.71	1.00											
WL Recog	.45	.54	.38	.39	.63	1.00										
BNT	.43	.33	.41	.35	.27	.27	1.00									
VR II	.54	.68	.59	.54	.69	.44	.35	1.00								
VR Recog	.37	.44	.46	.33	.42	.25	.20	.49	1.00							
DS Back.18	.11	.11	.15	.05	.02	.17	.22	.20	1.00							
LNS	.39	.46	.45	.52	.42	.22	.23	.44	.32	.26	1.00					
MC 5-8 .45	.38	.31	.36	.31	.16	.20	.40	.43	.42	.45	1.00					
TMT-B -.26	-.17	-.19	-.35	-.22	.02	-.15	-.23	-.31	-.06	-.29	-.30	1.00				
DS For	.06	-.07	.03	.10	-.08	.00	.15	-.05	.01	.45	.29	.27	-.09	1.00		
TMT-A -.27	-.23	-.21	-.36	-.21	-.13	-.33	-.24	-.38	-.22	-.30	-.33	.50	-.14	1.00		
MC 1-4 .23	.13	.07	.20	.13	-.06	.22	.28	.17	.21	.20	.43	-.26	.20	-.20	1.00	
BDS-2	.24	.23	.22	.20	.19	.10	.20	.27	.37	.13	.35	.46	-.32	.16	-.30	.33
Fluency .43	.39	.28	.40	.36	.20	.35	.38	.27	.12	.26	.35	-.22	-.05	-.27	.22	
CDT	.22	.18	.30	.16	.29	.26	.26	.35	.36	.19	.24	.35	-.29	.13	-.38	.25
HVOT	.44	.41	.41	.39	.41	.31	.40	.41	.38	.26	.45	.40	-.37	.10	-.51	.25
VR I	.53	.58	.55	.56	.59	.33	.35	.73	.48	.21	.54	.41	-.35	.02	-.41	.28
Praxis	.30	.25	.30	.24	.29	.28	.28	.33	.32	.13	.37	.38	-.32	.14	-.34	.32
SS	.21	.12	.22	.07	.06	-.06	.16	.28	.15	.21	.28	.28	-.25	.14	-.20	.23

LM I = Logical Memory I; LM II = Logical Memory II; LM Recog = Logical Memory Recognition; WL = Word List total; WL Recal = Word List Recall; WL Recog = Word List Recognition; BNT = Boston Naming Test; VR II = Visual Reproduction II; VR Recog = Visual Recognition Recognition; DS Back = Digit Span Backward; LNS = Letter-Number Sequencing; MC 5-8 = Mental Control (Items 5-8); TMT-B = Trailmaking B; DS For = Digit Span Forward; TMT-A = Trailmaking A; MC 1-4 = Mental Control (Items 1-4); BDS-2 = Behavioral Dyscontrol Scale - 2; Fluency = Verbal Fluency; CDT = Clock Drawing Test; HVOT = Hooper Visual Organization Test; VR I = Visual Reproduction I; Praxis = Constructional Praxis; SS = Spatial Span total.

(table continues)

Table 4 *(continued)*.

	BDS	Fluency	CDT	HVOT	VR I	Praxis	SS
LM I							
LM II							
LM Recog							
WL							
WL Recal							
WL Recog							
BNT							
VR II							
VR Recog							
DS Back							
LNS							
MC 5-8							
TMT-B							
DS For							
TMT-A							
MC 1-4							
BDS-2	1.00						
Fluency .26	1.00						
CDT	.36	.23	1.00				
HVOT	.31	.29	.46	1.00			
VR I	.44	.41	.41	.56	1.00		
Praxis	.35	.26	.53	.49	.50	1.00	
SS	.31	.10	.26	.29	.34	.17	1.00

LM I = Logical Memory I; LM II = Logical Memory II; LM Recog = Logical Memory Recognition; WL = Word List total; WL Recal = Word List Recall; WL Recog = Word List Recognition; BNT = Boston Naming Test; VR II = Visual Reproduction II; VR Recog = Visual Recognition Recognition; DS Back = Digit Span Backward; LNS = Letter-Number Sequencing; MC 5-8 = Mental Control (Items 5-8); TMT-B = Trailmaking B; DS For = Digit Span Forward; TMT-A = Trailmaking A; MC 1-4 = Mental Control (Items 1-4); BDS-2 = Behavioral Dyscontrol Scale - 2; Fluency = Verbal Fluency; CDT = Clock Drawing Test; HVOT = Hooper Visual Organization Test; VR I = Visual Reproduction I; Praxis = Constructional Praxis; SS = Spatial Span

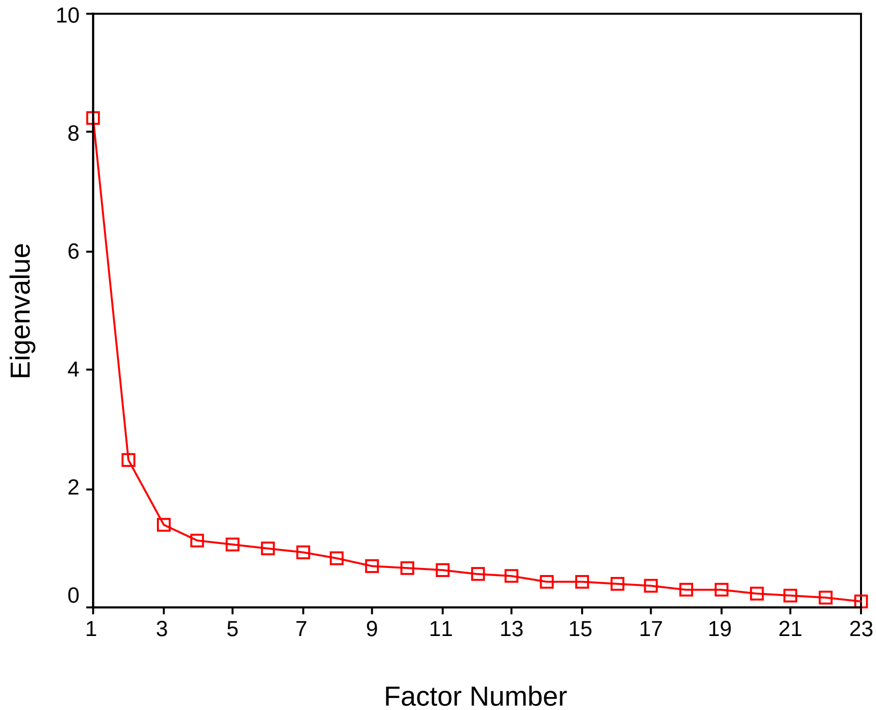

Figure 1. Scree plot.

REFERENCES

Baldo, J. & Shimamura, A. (1998). Verbal and category fluency in patients with frontal lobe lesions. *Neuropsychology, 12,* 259-267.

Baldo, J. V., Shimamura, A. P., Dellis, D. C., Kramer, J., & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. *Journal of the International Neuropsychological Society, 7*, 586-596.

Banken, J. A. (1985). Clinical utility of considering digits forward and digits backward as separate components of the Wechsler Adult Intelligence Scale-Revised. *Journal of Clinical Psychology, 41*, 686-691.

Barr, A., Benedict, R., Tune, L., & Brandt, J. (1992). Neuropsychological differentiation of Alzheimer's disease from vascular dementia. *International Journal of Geriatric Psychiatry, 7*, 621-627.

Black, F. W. (1986). Digit repetition in brain-damaged adults: Clinical and theoretical implications. *Journal of Clinical Psychology, 42*, 770-782.

Brannen, J. H., Badie, B., Moritz, C. H., et al. (2001). Reliability of functional MR imaging with word-generation tasks for mapping Broca's area. *American Journal of Neuroradiology, 22*, 1711-1718.

Brown, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing structural models* (pp. 136-162). Newbury Park: Sage Publications.

Butters, N., Salmon, D., Cullum, C., Cairns, P., Troster, A., & Jacobs, D. (1988). Differentiation of amnestic and demented patients with the Wechsler Memory Scale-Revised. *Clinical Neuropsychologist, 2*, 133-148.

Cahn-Weiner, D. A., Sullivan, E. V., Shear, P. K., et al. (1999). Brain structural and cognitive correlates of clock drawing performance in Alzheimer's disease. *Journal of the International Neropsychological Society, 5*, 502-509.

Cirillo, M., Swearer, J., Kane, K., & Lavoie, M. (1999). Influence of perceptual organization and naming on the HVOT in an older sample. *Journal of the International Neuropsychological Society, 5*(2), 119.

Crossley, M., D'Arcy, C., & Rawson, N. S. B. (1997). Letter and category fluency in community-dwelling Canadian seniors: A comparison of normal participants to those with dementia of the Alzheimer or vascular type. *Journal of Clinical and Experimental Neuropsychology, 19*, 52-62.

Crowe, S. (2000). Does the letter number sequence task measure anything more than digit span? *Assessment, 7*, 113-117.

Diesfeldt, H. F. A. (2004). Executive functioning in psychogeriatric patients: Scalability and construct validity of the Behavioral Dyscontrol Scale (BDS). *International Journal of Geriatric Psychiatry, 19*, 1065-1073.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *California Verbal Learning Test: Adult version.* San Antonio: Harcourt Brace & Company.

Ecklund-Johnson, E., Miller, S. A., & Sweet, J. J. (2004). Confirmatory factor analysis of the Behavioral Dyscontrol Scale in a mixed clinical sample. *Clinical Neuropsychologist, 18*(3), 395-410.

Fama, R., Sullivan, E. V., Shear, P. K., Cahn-Weiner, D. A., Yesavage, J. A., Tinkleberg, J. R., & Pfefferbaum, A. (1998). Fluency performance patterns in Alzheimer's disease and Parkinson's disease. *Clinical Neuropsychologist, 12,* 487-499.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini Mental State". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Forstl, H., Burns, A., Levy, R., & Cairns, N. (1993). Neuropathological basis for drawing disability (constructional apraxia) in Alzheimer's disease. *Psychological Medicine, 23*, 623-629.

Fowler, P. C., Richards, H. C., Boll, T. J., & Berent, S. (1987). A factor model of an extended Halstead Battery and its relationship to an EEG Lateralization index for epileptic adults. *Archives of Clinical Neuropsychology, 2*, 81-92.

Freedman, M., Kaplan, E., Delis, D., & Morris, R. (1994). *Clock Drawing: A neuropsychological analysis.* New York: Oxford University Press.

Frith, C., Friston, K., Liddle, P., & Frackowiak, D. (1991). A PET study to word finding. *Neuropsychologia, 29*,1137-1148.

Gaudino, E. A., Geisler, M. W., & Squires, N. K. (1995). Construct validity in the Trail Making Test: What makes Trail B harder? *Journal of Clinical and Experimental Neuropsychology, 17*, 529-535.

Gfeller, J. D., Meldrum, D. L., & Jacobi, K. A. (1995). The impact of constructional impairment on the WMS-R visual reproduction subtests. *Journal of Clinical Psychology, 51*, 58-63.

Greve, K.W., Lindberg, R. F., Bianchini, K. J., & Adams, D. (2000). Construct validity and predictive value of the HVOT in stroke rehabilitation. *Applied Neuropsychology, 7*, 215-222.

Grigsby, J., Kaye, K., Baxter, J., Shetterly, S. M., & Hamman, R. F. (1998). Executive cognitive abilities and functional status among community-dwelling older persons in the San Luis Valley Health and Aging Study. *Journal of the American Geriatrics Society, 46*(5), 590-596.

Grigsby, J., Kaye, K., Kowalsky, J., & Kramer, A. M. (2002). Association of behavioral self-regulation with concurrent functional capacity among stroke rehabilitation patients. *Journal of Clinical Geropsychology, 8*, 25-33.

Grigsby, J., Kaye, K., & Robbins, L. J. (1992). Reliabilities, norms and factor structure of the Behavioral Dyscontrol Scale. *Perceptual and Motor Skills, 74*, 883-892.

Groth-Marnat, G., Gallasgher, R. E., Hale, J. B., & Kaplan, E. (2000). The Wechsler intelligence scales. In G. Groth-Marnat (Ed.), *Neuropsychological assessment in clinical practice: A guide to test interpretation and integration* (pp. 129-194). New York: John Wiley & Sons.

Haut, M. W., Weber, A. M., Wilhelm, K. L., Keefover, R. W., & Rankin, E. D. (1994). The Visual Reproduction subtest as a measure of visual perceptual/constructional functioning in dementia of the Alzheimer's type. *Clinical Neuropsychologist, 8*, 187-192.

Heilbronner, R. L., Henry, G. K., Buck, P., Adams, R. L., & Fogle, T. (1991). Lateralized brain damage and performance on Trail Making A and B, Digit Span Forward and Backward, and TPT memory and location. *Archives of Clinical Neuropsychology, 6*, 251-258.

Hooper, H. E. (1958). *Hooper visual organization test manual.* Los Angeles: Western Psychological Services.

Johnstone, B., & Wilhelm, K. (1997). The construct validity of the Hooper Visual Organization Test. *Assessment, 4*, 243-248.

Jonsdottir, M. K. (1997). Hooper Visual Organization Test: Is identification without mental assembly unavoidable? *Journal of the International Neuropsychological Society, 3*, 30.

Kaltreider, L. B., Cicerello, A. R., Lacritz, L. H., Weiner, M. F., Honig, L. S., Rosenberg, R. N., & Cullum, C. M. (2000). Comparison of the Cerad and CVLT list-learning tasks in Alzheimer's disease. *Clinical Neuropsychologist, 14*, 269-274.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *The Boston Naming Test*. Philadelphia: Lea & Febiger.

Kaufman, A. S., McLean, J., & Reynolds, C. (1991). Analysis of WAIS-R factor patterns by sex and race. *Journal of Clinical Psychology, 47*, 548-557.

Kaye, K., Grigsby, J., Robbins, L. J., & Korzun, B. (1990). Prediction of independent functioning and behavior problems in geriatric patients. *Journal of the American Geriatric Society, 38*, 1304-1310.

Lacks, P. (2000). Visuoconstructive abilities. In G. Groth-Marnat (Ed.), *Neuropsychological assessment in clinical practice: A guide to test interpretation and integration* (pp. 401-436). New York: John Wiley & Sons.

Larrabee, G., Kane, R., & Schuck, J. (1983). Factor analysis of the WAIS and Wechsler Memory Scale: An analysis of the construct validity of the Wechsler Memory Scale. *Journal of Clinical Neuropsychology, 5*, 159-168.

Larrabee, G. J., Kane, R. L., Schuck, J. R., & Francis, D. J. (1985). Construct validity of various memory testing procedures. *Journal of Clinical and Experimental Neuropsychology, 7*, 239-250.

Larrabee, G. J., Curtiss, G. (1995). Construct validity of various verbal and visual memory tests. *Journal of Clinical and Experimental Neuropsychology, 17*, 536-547.

Leonberger, F. T., Nicks, S. D., Goldfather, P. R., & Munz, D. C. (1991). Factor analysis of the Wechsler Memory Scale-Revised within a comprehensive neuropsychological battery. *Neuropsychology, 6*, 239-249.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment* (4th ed.). New York: Oxford University Press.

Libon, D. J., Malamut, B. L., Swenson, R., Sands, L. P., & Cloud, B. S. (1996). Further analysis of clock drawings among demented and non-demented older subjects. *Archives of Clinical Neuropsychology, 11*, 193-205.

Libon, D. J., Swenson, R. A., Barnoski, E. J., & Sands, L. P. (1993). Clock drawing as an assessment tool for dementia. *Archives of Clinical Neuropsychology, 8*, 405-415.

Loewenstein, D. A., Ownby, R., Schram, L., Acevedo, A., Rubert, M., & Arguelles, T. (2001). An evaluation of the NINCDS-ADRDA neuropsychological criteria for the assessment of Alzheimer's disease: A confirmatory factor analysis of single versus multi-factor models. *Journal of Clinical and Experimental Neuropsychology, 23*, 274-284.

Mendez, M. F., Ala, T., & Underwood, K. L. (1992). Development of scoring criteria for the clock drawing task in Alzheimer's disease. *Journal of the American Geriatrics Society, 40*, 1095-1099.

Merten, T. (2005). Factor structure of the Hooper Visual Organization Test: A cross-cultural replication and extension. *Archives of Clinical Neuropsychology, 20*, 123-128.

Monsch, A. U., Bondi, M. W., Butters, N., Paulsen, J. S., Salmon, D. P., Brugger, P., & Swenson, M. R. (1994). A comparison of category and letter fluency in Alzheimer's disease and Huntington's disease. *Neuropsychology, 8*, 25-30.

Morris, J. C., Heyman, A., Mohs, R. C., et al. (1989). The Consortium to Establish a Registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. *Neurology, 39*, 1159-65.

Paolo, A., Cluff, R. B., & Ryan, J. J. (1996). Influence of perceptual organization and naming on the Hooper Visual Organization Test. *Neuropsychiatry, Neuropsychology and Behavioral Neurology, 9*, 254-257.

Parks, R., Loewenstein, D., Dodrill, K., Barker, W., Yoshii, F., Chang, J., Emran, A., Apicella, A., Sheramata, W., & Duara, R. (1988). Cerebral metabolic effects of a verbal fluency test: A PET scan study. *Journal of Clinical and Experimental Neuropsychology, 10*, 565-75.

Paul, R., Cohen, R., Moser, D., Ott, B., Zawacki, T., & Gordon, N. (2001). Performance on the Hooper Visual Organization Test in patients diagnosed with subcortical vascular dementia: Relation to naming performance. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology, 14*(2), 93-97.

Prigatano, G. P. (1978). Wechsler Memory Scale: A selective review of the literature. *Journal of Clinical Psychology, 34*, 816-832.

Ricker, J. H., & Axelrod, B. N. (1995). Hooper Visual Organization Test: Effects of object naming ability. *The Clinical Neuropsychologist, 9*, 57-62.

Rosen, W. G., Mohs, R. C., & Davis, K. L. (1984). A rating scale for Alzheimer's disease. *American Journal of Psychiatry, 141*, 1356-1364.

Roth, D. L., Conboy, T. J., Reeder, K. P., & Boll, T. J. (1990). Confirmatory factor analysis of the Wechsler Memory Scale-Revised in a sample of head-injured patients. *Journal of Clinical and Experimental Neuropsychology, 12*, 834-842.

Ryan, J. J., Rosenberg, S. J., & Heilbronner, R. L. (1984). Comparative relationship of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and the Wechsler Adult Intelligence Scale (WAIS) to the Wechsler Memory Scale (WMS). *Journal of Behavioral Assessment, 6*, 37-43.

Smith, G. E., Malec, J. F., & Ivnik, R. J. (1992). Validity of the construct of nonverbal memory: A factor-analytic study in a normal elderly sample. *Journal of Clinical and Experimental Neuropsychology, 14*, 211.

Spreen, O., & Strauss, E. (1998). *A compedium of neuropsychological tests: Administration, norms, and commentary* (2nd ed.). New York: Oxford University Press.

Suchy, Y., Blint, A., & Osmon, D. S. (1997). Behavioral Dyscontrol Scale: Criterion and predictive validity in an inpatient rehabilitation unit population. *Clinical Neuropsychologist, 11*(3), 258-265.

Tabachnik, B. G., & Fidell, L. A. (2001). *Using multivariate statistics* (4th ed.). Needham Heights, MA: Allyn & Bacon.

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from young and older healthy adults. *Neuropsychology, 11*, 138-146.

Troyer, A., Moscovitch, M., Winocur, G., Alexander, M., & Stuss, D. (1998). Clustering and switching on verbal fluency: The effects of focal frontal- and temporal-lobe lesions. *Neuropsychologia, 36*, 499-504.

Tuokko, H., Hadjistavropoulos, T., Miller, J. A., & Beattie, B. L. (1992). The clock test: A sensitive measure to differentiate normal elderly from those with Alzheimer's disease. *Journal of the American Geriatrics Society, 40*, 579-584.

Wechsler, D. (1997). *Wechsler Memory Scale-third edition*. San Antonio, TX: The Psychological Corporation.

Welsh, K. A., Butters, N., Hughes, J. P., Mohs, R. C., & Heyman, A. (1992). Decection and staging of dementia in Alzheimer's disease. *Archives of Neurology, 49*, 448-452.

Welsh, K., Butters, N., Hughes, J., Mohs, R., & Heyman, A. (1991). Detection of abnormal memory decline in mild cases of Alzheimer's disease using CERAD neuropsychological measures. *Archives of Neurology, 48*, 278-281.

Wolf-Klein, G. P., Silverstone, F. A., Levy, A. P., & Brod, M. S. (1989). Screening for Alzheimer's disease by clock drawing. *Journal of the American Geriatric Association, 37*, 730-734.

Woodard, J. L., Salthouse, T. A., Godsall, R. E., & Green, R. C. (1996). Confirmatory factor analysis of the Mattis Dementia Rating Scale in patients with Alzheimer's disease. *Psychological Assessment, 8*(1), 85-91.

Woodard, J. L., Goldstein, F. C., Roberts, V. J., & McGuire, C. (1999). Convergent and discriminant validity of the CVLT (Dementia Version). *Journal of Clinical and Experimental Neuropsychology, 21*, 553-558.

Woodruff, G. R., Mendoza, J. E., Dickson, A. L., Blanchard, E., & Christenberry, L. B. (1995). The effects of configural differences on the Trail Making Test. *Archives of Clinical Neuropsychology, 10*, 408 (abstract).